(54) Title: OPTICAL SENSOR

(54) 発明の名称: 光検出装置
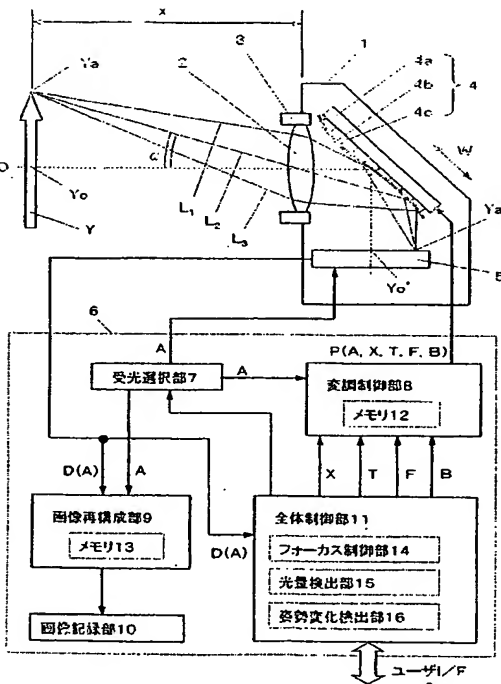
7...LIGHT-RECEPTION SELECTING UNIT
9 . IMAGE RESTORING UNIT
13...MEMORY
10...IMAGE RECORDING UNIT
8 . MODULATION CONTROLLING UNIT
12...MEMORY
11...TOTAL CONTROLLING UNIT
14...FOCUS CONTROLLING UNIT
15...LIGHT QUANTITY SENSING UNIT
16...POSTURE CHANGE SENSING UNIT
a...USER I/F

(57) Abstract: An optical sensor is disclosed which comprises a spatial light modulator for modulating the phase of an incident light, a light-receiving device having a plurality of light-receiving regions for receiving the light whose phase is modulated by the spatial light modulator, a light-reception selecting unit for selecting at least one region among the light-receiving regions and having the selected light-receiving region function effectively, and a modulation controlling unit for providing a modulation pattern to the spatial light modulator according to the light-receiving region selected by the light-reception selecting unit.

(57) 要約: 本発明の光検出装置は、入射光の位相を変調する空間光変調器と、前記空間光変調器によって位相が変調された前記光を受ける複数の受光領域を備えた受光素子と、前記複数の受光領域から少なくとも 1 つの受光領域を選択し、選択した受光領域を有効に機能させる受光選択部と、前記受光選択部によって選択された前記受光領域に応じた変調パターンを前記空間光変調器に与える変調制御部と、を備える。

(84) 指定国 *(表示のない限り、全ての種類の広域保護が可能)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), ヨーロッパ (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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DESCRIPTION

OPTICAL SENSOR

TECHNICAL FIELD

5   The present invention relates to an optical detection system including a spatial light modulator and more particularly relates to an optical detection system having the function of controlling an image being formed on its photodetector.

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BACKGROUND ART

Generally speaking, a compound lens, consisting of any number of lenses in any of various combinations (e.g., seven lenses in six groups or eleven lenses in ten groups), is

15 often used in an imaging optical system such as a camera. According to a paraxial theory, such a compound lens is equivalent to a single convex lens. However, such approximation is accurate enough only within a relatively narrow range near the optical axis. Accordingly, in actually

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handling a rather big image, an aberration associated with an angle of view is a problem. Also, in treating multiple wavelengths as in a color image, a chromatic aberration is a problem.

5   To reduce such aberrations, various combinations of refractive indices and optical surface shapes have been proposed for use in lenses to make up a compound lens. However, to minimize the aberration associated with the angle of view and the chromatic aberration over the entire area of

10 a photodetector, the compound lens needs to consist of a lot of lenses, which increases the overall cost of the required members, the assembling and adjustment costs, and the size of the optical instrument, too.

In order to reduce the overall size of a lens system, it

15 is effective to increase the refractive powers of respective lenses. However, the aberrations resulting from the angle of view and the difference in wavelength would rather increase by doing just that. Nevertheless, if the number of lenses to make up the compound lens were increased to avoid that

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situation, then the optical instrument would get too much complicated or bulky.

As can be seen, reduction of the aberrations and simplification of the optical system are contradictory purposes, which are hard to achieve at the same time and are still key issues in optics design of today.

Also, in a zoom lens optical system, for example, the aberrations must be reduced with the magnification of imaging changed, thus making it even more difficult to simplify and downsize the optical system.

Furthermore, not just the lens system but also a light quantity control mechanism such as a diaphragm and a shutter increase the size of an optical instrument. This is particularly remarkable in an optical system with a compound lens consisting of a lot of lenses such as a wide-angle lens or a zoom lens. However, depending on the angle of incidence of a bundle of rays entering a lens, the bundle of rays may pass just a portion of each lens, thus making it difficult to design and arrange the optical elements so as to adjust the

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light quantity uniformly over the entire area of the photodetector. For example, the diaphragm must be arranged at a position where the illumination can be changed at the same ratio as the center portion over the entire area of the

5   photodetector. This condition imposes a constraint in designing an optical system.

The presence of such a light quantity control mechanism and the constraints on its arrangement constitute another obstacle to simplifying and downsizing the optical system.

10   Meanwhile, not only conventional passive optical elements with fixed optical surfaces such as a glass lens or a prism but also active optical elements with deformable optical surfaces have been developed recently.

Examples of those active optical elements include an

15   optical element that uses a lens with an encapsulated transparent liquid as a variable-focus lens by getting the lens driven by a piezoelectric element (see, for example, Japanese Laid-Open Publication No. 2001-257932, which will be referred to herein as "Document No. 1"). Document No. 1

discloses a configuration in which multiple images are sampled with the focal point of this variable-focus lens switched at high speed and an image that is in best focus with the object is extracted by an image processing technique, thereby obtaining an all in focus image. This Patent Document No. 1 also discloses a configuration for correcting the shift of an image (e.g., variation in magnification and distortion of the image) resulting from a variation in focal length.

Also, in another proposed configuration, a deformable mirror called "Digital Micromirror Device" (DMD, a product name) is provided on the optical path of an imaging optical system and the number of ON-state mirrors or the time of their ON-state periods is controlled, thereby making up an optical diaphragm device (see, for example, Japanese Laid-Open Publication No. 11-231373, which will be referred to herein as "Document No. 2"). This Document No. 2 discloses a configuration for obtaining an arbitrary aperture shape by controlling the mirror driving pattern.

However, the conventional configurations described above

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have the following drawbacks.

Firstly, only a few types of aberrations can be corrected and reduction of the aberrations over the entire area of the photodetector and simplification of the optical system are hard to realize at the same time. Document No. 1 does disclose a configuration that can be used effectively to correct the focal point shifting and image distortion but does not disclose any configuration for reducing aberrations of different modes such as coma aberration and astigmatism. For example, the aberration associated with the angle of view is mostly a coma aberration or astigmatism, which is hard to correct effectively by the configuration disclosed in Document No. 1. Likewise, a chromatic aberration due to a wavelength difference or an aberration caused by a change of the magnification of imaging includes a lot of components that can never be corrected just by changing the focal length, and is also hard to correct effectively according to the configuration disclosed in Document No. 1.

Accordingly, even when the configuration of Document No.

1 is adopted, a compound lens consisting of almost the same

number of lenses is also needed to reduce the angle-of-view

aberration and chromatic aberration over the entire area of

the photodetector. Consequently, reduction of the aberrations

5   and simplification of the optical system are still difficult

to achieve at a time to virtually the same degree. Document

No. 2 does not provide any particular configuration for

overcoming this problem, either.

Secondly, the aberration correcting mechanism and light

10   quantity control mechanism are both required, thus making it

difficult to simplify the optical system.   In   the

configuration of Document No. 2, an imaging optical system

with a compound lens consisting of a lot of lenses is

provided as the aberration correcting mechanism and a DMD and

15   its driver circuit are provided as the light quantity control

mechanism.   These   are   separately   provided   as   independent

mechanisms for fulfilling distinct purposes.   And Document No.

2 discloses no configuration that can function as both of

these two mechanisms at the same time.   Thus, the presence of

20   these two mechanisms increases the number of members required,

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the complexity of the assembling and adjustment processes, and the overall cost and size of the entire optical system. Document No. 1 does not provide any particular configuration for overcoming this problem, either.

5   Thirdly, it is difficult to reduce the size of the optical system due to the constraint on the arrangement of the light quantity control mechanism. In the configuration of Document No. 2, the quantity of the incoming light is controlled by getting the incoming light deviated by the DMD 10 out of the range of the photodetector. However, to deviate the incoming light totally outside of the photodetector, at least a certain distance must be provided between the photodetector and the DMD. This distance heavily depends on the angle of deviation caused by the DMD and the size of the 15 photodetector, which makes it difficult to downsize the optical system.

Furthermore, in the configuration of Document No. 2, the incoming light is once converged toward a point, where the DMD is provided as a diaphragm. Thus, the overall optical system

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has an increased size. In Document No. 2, the constraint on the arrangement of the diaphragm to control the light quantity uniformly over the entire area of the photodetector interferes with the desired downsizing. In this respect, Document No. 2

5   discloses any particularly effective means for improvement. Document No. 2 discloses a configuration for obtaining an arbitrary aperture shape by controlling the mirror driving pattern. However, it is impossible to independently control the light quantities for respective areas of the photodetector

10 with only one aperture shape. Thus, the non-uniformity of the light quantity control cannot be eliminated essentially. Document No. 1 does not provide any particular configuration for overcoming this problem, either.

It should be noted that Japanese National Phase

15 Publication No. 2002-525685 discloses a technique of getting light rays, which have come from multiple different portions of an object, sequentially imaged on a single photosensitive region one after another but still cannot overcome the problems described above.

In order to overcome the problems described above, an object of the present invention is to provide an optical detection system, which can reduce the aberrations over the entire area of the photodetector, can control the light quantity appropriately, and can simplify the optical system at the same time.

DISCLOSURE OF INVENTION

An optical detection system according to the present invention includes: a spatial light modulator for modulating the phase of incoming light; a photodetector having a plurality of photosensitive areas to receive the light of which the phase has been modulated by the spatial light modulator; a photosensor selecting section for selecting at least one of the photosensitive areas and activating the selected photosensitive area effectively; and a modulation control section for providing a modulation pattern, associated with the photosensitive area that has been selected by the photosensor selecting section, for the spatial light modulator.

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In one preferred embodiment, the photosensor selecting section cyclically switches the photosensitive areas to select by a time sequential technique, and synchronously with this switching operation, the modulation control section provides

5 a modulation pattern, which produces appropriate imaging ability in the photosensitive area selected, for the spatial light modulator.

In another preferred embodiment, the modulation control section picks one of a plurality of prepared modulation

10 patterns according to the photosensitive area selected.

In another preferred embodiment, the spatial light modulator is arranged on an optical path of an imaging optical system.

In another preferred embodiment, the incoming light

15 entering the spatial light modulator includes light rays with multiple different wavelengths.

In another preferred embodiment, the photosensor selecting section chooses, as light to be modulated, a light ray falling within a particular wavelength range from the

20 light rays with the multiple wavelengths.

In another preferred embodiment, the photosensor selecting section cyclically switches the light rays to choose by a time sequential technique, and synchronously with this switching operation, the modulation control section provides a modulation pattern, which produces appropriate imaging ability with respect to the light ray chosen, for the spatial light modulator.

In another preferred embodiment, the imaging optical system selectively exhibits one of multiple types of imaging characteristics. The optical detection system further includes an imaging information sensing section for sensing information about the imaging characteristic that has been selected from the multiple types of imaging characteristics. In accordance with the output of the imaging information sensing section, the modulation control section provides a modulation pattern, which produces an appropriate imaging ability, for the spatial light modulator.

In another preferred embodiment, the imaging characteristic is an imaging magnification.

In another preferred embodiment, the modulation control

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section provides a modulation pattern, which deviates the incoming light that has entered at least a portion of the spatial light modulator out of the photosensitive area selected, for the spatial light modulator.

5   In another preferred embodiment, the modulation control section provides a modulation pattern, which changes the area of that portion of the spatial light modulator, for the spatial light modulator.

In another preferred embodiment, the modulation control section selectively provides either a first modulation pattern, which makes the area of that portion of the spatial light modulator relatively large, or a second modulation pattern, which makes the area of that portion of the spatial light modulator relatively small, for the spatial light modulator, and controls the respective durations of the first and second modulation patterns.

In another preferred embodiment, the light that has been deviated out of the photosensitive area selected is incident on another photosensitive area of the photodetector.

20   In another preferred embodiment, the optical detection

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system further includes a position change detecting section for detecting a change of the position of the optical detection system. In accordance with the output of the position change detecting section, the modulation control section generates a modulation pattern that compensates for a shift in focal point caused by the position change.

In another preferred embodiment, each of the photosensitive areas in the photodetector has a plurality of pixels arranged at a pitch, and the modulation control section provides a modulation pattern, which focuses the incoming light at multiple points that are shifted from each other by a distance corresponding to the pixel pitch of the photodetector, for the spatial light modulator.

In another preferred embodiment, the spatial light modulator is a deformable mirror.

In another preferred embodiment, the deformable mirror includes: a plurality of light reflecting areas that are arranged on a substrate; and an actuator for displacing the light reflecting areas at least perpendicularly to the substrate.

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In another preferred embodiment, the deformable mirror is coupled to multiple actuators that are associated with the respective light reflecting areas. By driving the actuators independently of each other, the light reflecting areas are

5 displaced perpendicularly to the substrate and/or tilted with respect to the substrate.

In another preferred embodiment, the spatial light modulator is a liquid crystal element.

In another preferred embodiment, each of the

10 photosensitive areas of the photodetector includes a photoelectric modulating section. The optical detection system further includes: a memory for storing the outputs of the photoelectric modulating section in the photosensitive area that has been selected by the photosensor selecting

15 section; and a reconstructing section for reconstructing an overall image by rearranging the outputs stored in the memory.

In another preferred embodiment, the photodetector is a storage medium, of which a physical property changes when exposed to a radiation, and includes a shutter member that

20 allows the photosensor selecting section to selectively

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transmit or cut off the incoming light.

In another preferred embodiment, the spatial light modulator functions as an optical low pass filter.

Another optical detection system according to the present invention includes: a spatial light modulator for modulating the phase of incoming light including multiple light rays with different wavelengths; a photodetector for selectively receiving the light, of which the phase has been modulated by the spatial light modulator, according to its wavelength; a photosensor selecting section for selecting the wavelength of the effective light ray to receive from the multiple wavelengths; and a modulation control section for providing a modulation pattern, associated with the wavelength that has been selected by the photosensor selecting section, for the spatial light modulator.

Still another optical detection system according to the present invention includes: a spatial light modulator, which is provided on an optical path of an imaging optical system that selectively exhibits one of multiple types of imaging characteristics so as to modulate the phase of incoming characteristics so as to modulate the phase of incoming

light; a photodetector for receiving the light of which the phase has been modulated by the spatial light modulator; an imaging information sensing section for sensing information about the imaging characteristic that has been selected from 5 the multiple types of imaging characteristics; and a modulation control section for providing a modulation pattern for the spatial light modulator in accordance with the output of the imaging information sensing section.

The imaging characteristic is an imaging magnification.

10 Yet another optical detection system according to the present invention includes: a spatial light modulator, which is provided on an optical path of an imaging optical system so as to modulate incoming light; a modulation control section for providing a plurality of modulation patterns for the 15 spatial light modulator; a photodetector having a plurality of photosensitive areas to receive the incoming light that has been modulated by the spatial light modulator; and a photosensor selecting section for selecting one of the photosensitive areas to receive the light effectively. The 20 modulation control section generates a modulation pattern to

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control the quantity of the incoming light for the photosensitive area that has been selected by the photosensor selecting section.

In one preferred embodiment, the optical detection

5 system further includes a light quantity detecting section for detecting the respective quantities of light received by the photosensitive areas, and the modulation control section generates the modulation pattern in accordance with the output of the light quantity detecting section.

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BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a diagram schematically showing a configuration for an optical detection system according to a first preferred embodiment of the present invention.

15 FIG. 2 is an exploded perspective view of a deformable mirror according to the first preferred embodiment of the present invention.

FIG. 3 is a diagram showing a configuration for a photodetector according to the first preferred embodiment of

20 the present invention.

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FIG. **4** shows how to operate the diaphragm and shutter of the deformable mirror **4**.

FIG. **5** shows how the deformable mirror **4** functions as an optical low pass filter.

5   FIG. **6** shows how the deformable mirror **4** corrects blurring.

FIG. **7** is a diagram schematically showing a configuration for an optical detection system according to a second preferred embodiment of the present invention.

10   FIG. **8** is a diagram schematically showing a configuration for an optical detection system according to a third preferred embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

15 EMBODIMENT 1

Hereinafter, an optical detection system according to a first preferred embodiment of the present invention will be described with reference to FIGS. **1** through **6**.

First, referring to FIG. **1**, illustrated is a schematic

20 configuration for an optical detection system according to

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this preferred embodiment. In the housing **1** of the optical detection system shown in FIG. **1**, a lens **2**, a lens moving mechanism **3**, a deformable mirror **4**, a photodetector **5**, and a controller **6** are provided. As shown as a block diagram in FIG. **1**, the controller **6** includes a photosensor selecting section **7**, a modulation control section **8**, an image reconstructing section **9**, an image storage section **10** and an overall control section **11**.

The lens **2** is an objective lens for condensing the light that has come from an object **Y**, which is the target to be imaged. After having passed through the lens **2**, the incoming light has its phase modulated by the deformable mirror **4** functioning as a spatial light modulator. Then, the incoming light is reflected by the deformable mirror **4** and converged on the photodetector **5**. FIG. **1** illustrates a state in which incoming light that has come from a point **Ya** on the object **Y** is focused at a point **Ya'** on the photodetector **5**. In this case, the distance from the optical detection system to the object **Y** is supposed to be x and the angle of the incoming light is supposed to be α. Three possible optical paths **L1**,

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L2 and **L3** of the incoming light reaching the point **Ya'** from the point **Ya** are also shown in FIG. 1. To produce an image of the point **Ya** at the point **Ya'** clearly, all optical paths, including the three optical paths **L1**, **L2** and **L3**, may have an

5 identical optical path length. Alternatively, the optical path lengths may also be defined so as to be different from each other by an integral multiple of the wavelength. That is to say, it is only necessary that the phases of incoming light rays, starting from the point **Ya** and traveling along those

10 paths, match with each other at the point **Ya'**. This condition is satisfied herein by deforming the deformable mirror **4**. The target values of deformation at respective points on the deformable mirror **4** may be calculated as functions of only α and **x**. Thus, in this preferred embodiment, those values are

15 stored as a table and the α - and x-related values are read out as an address. There are five functions of the deformable mirror **4** as spatial light modulator. One of the five is this aberration correcting function and the other four are a shuttering function, a stopping function, an optical low pass

20 filter function and a blurring correcting function. These

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functions will be described in further detail later.

The lens **2** is designed so as to have such a surface shape that when the deformable mirror **4** is not deformed (i.e., has a flat plane surface), a point **Yo** of the object **Y** near the

5 optical axis **O** is rather well imaged at a point **Yo'** on the photodetector **5**.

The lens moving mechanism **3** moves the lens **2** back and forth along the optical axis **O**, thereby controlling the focal point.

10 The deformable mirror **4** is obtained by arranging a lot of deformable micromirrors **4b** on a substrate **4b**. This deformable mirror may be implemented with the configuration that the applicant of the present application disclosed in the previous related PCT International Application No. PCT/JP02/12344.

15 Each of those micromirrors **4b** has a very small reflective plane, which may be either about 100-200 μ m square or rectangular (of which the longer side is defined in the W direction). The micromirrors **4b** are arranged as a two-dimensional array with a gap of about 1 μ m provided between

20 two adjacent micromirrors, thereby defining an overall

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reflective plane. The displacement of those micromirrors **4b** perpendicular to the substrate **4a** and/or the tilt of the micromirrors **4b** with respect to the substrate **4a** may be controlled independently of each other by the actuators **4c**

5 connected to the respective back surfaces of the micromirrors **4b**.

This deformable mirror **4** will be described more fully with reference to FIG. 2, which is an exploded perspective view of the deformable mirror **4** according to the first

10 preferred embodiment of the present invention. In FIG. 2, just one micromirror **4b** and its associated actuator **4c** are illustrated on a large scale.

As the fixed portion of the actuator **4c**, an insulating layer **21** is provided on a substrate **4a** and a base **22** and fixed

15 electrodes **23**, **24** and **25** are arranged on the insulating layer **21**. The base **22** and fixed electrodes **23** to **25** are formed by patterning a conductive film of aluminum (Al), polysilicon or any other suitable material. Each of these fixed electrodes **23**, **24** and **25** is divided into two fixed-electrode pieces **23a** &

20 **23b**, **24a** & **24b** and **25a** & **25b**. These fixed-electrode pieces

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23a, 23b, 24a, 24b, 25a and 25b are connected to the driver

circuit on the substrate 4a by way of via metals (not shown),

which are provided in the insulating layer 21. The driver

circuit can apply mutually independent voltages, all of which

5   fall within the range of 0 V to 5 V, to the fixed-electrode

pieces 23a, 23b, 24a, 24b, 25a and 25b. Each of the voltages

applied to these six fixed-electrode pieces 23a, 23b, 24a,

24b, 25a and 25b may be set to a multi-bit value of around 16

bits, for example. On the other hand, the base 22 is

10   grounded. A portion of the base 22 functions as a supporting

post 22a for supporting the movable electrodes.

As the movable portion of the actuator 4c, yokes 27, 28

and 29 are secured to the supporting post 22a via a hinge 26.

Furthermore, an intermediate coupling member 30 for coupling

15   these yokes 27, 28 and 29 to the micromirror 4b is also

provided.

These yokes 27, 28 and 29 face their associated fixed

electrodes 23, 24 and 25, respectively, so as to function as

"movable electrodes". The yokes 27, 28 and 29 are formed by

20   patterning an electrically conductive material such as

aluminum (Al) or polysilicon, and are electrically continuous with the base 22 so as to have the ground potential. Each of these yokes 27, 28 and 29 has a first portion 27a, 28a or 29a and a second portion 27b, 28b or 29b, which respectively face

5   the fixed-electrode pieces 23a & 23b, 24a & 24b and 24a & 25b. For example, if a drive voltage is applied to the fixed-electrode piece 23a for the yoke 27, then the first portion 27a will be attracted toward the fixed-electrode piece 23a. On the other hand, if a drive voltage is applied to the fixed-

10   electrode piece 23b, then the second portion 27b will be attracted toward the fixed-electrode piece 23b. In this manner, the rotational force can be produced around the axis A of rotation either clockwise CW or counterclockwise CCW. The same statement applies to the other yokes 28 and 29, too.

15   The intermediate coupling member 30 includes three protrusions 30a, 30b and 30c, which are coupled to the second portion 27b of the yoke 27, the first portion 27a of the yoke 28 and the second portion 29b of the yoke 29, respectively. Accordingly, by driving and rotating the yokes 27, 28 and 29

20   independently of each other, the displacements of the

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protrusions **30a**, **30b** and **30c** are controllable independently

and the position of the intermediate coupling member **30** is

fixed. The micromirror **4b** and intermediate coupling member **30**

are coupled together at the hatched portion **30d**, which is

5 approximately the center portion of the intermediate coupling

member **30**. Thus, the position of the intermediate coupling

member **30** defines the position of the micromirror **4b**. As is

clear from the foregoing description of the configuration of

this preferred embodiment, by applying drive voltages

10 selectively and independently to the fixed-electrode pieces

23a, **23b**, **24a**, **24b**, **25a** and **25b**, the micromirror **4b** can be

driven bidirectionally (i.e., positive and negative

directions), no matter whether the micromirror **4b** needs to be

displaced in the z direction or tilted around the x axis

15 and/or y axis.

The deformable mirror **4** will be further described with

reference to FIG. **1** again.

FIG. **1** illustrates a state where each micromirror **4b** and

its adjacent micromirrors have similar degrees of displacement

20 on their peripheries so as to form a continuum (i.e., so that

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the overall reflective surface defines one continuous curved surface). This curved surface may be defined so as to have any arbitrary shape and functions as a reflective mirror of which the surface shape is controllable actively. Naturally,

5   it is possible to control the displacement such that each micromirror **4b** and its adjacent micromirrors have different degrees of displacement on their peripheries so that the overall reflective surface is discontinuous. The respective positions of the micromirrors **4b** may be controlled

10 independently of each other. Accordingly, the deformable mirror **4** may also function as a diffraction grating of any of various shapes, and can control the quantity and focal point of the diffracted light on an order-by-order basis by changing its shape. By controlling the degrees of displacement of the

15 respective micromirrors **4b** in this manner, the incoming light **8** can have its optical path length changed and can be subjected to any arbitrary phase conversion. As to the target values of displacement of these micromirrors **4b** (i.e., as to the modulation pattern of the deformable mirror **4**), a number

20 of modulation patterns are prepared and stored in a memory **12**

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provided for the modulation control section **8**. And when an address **A** specifying a photosensitive area is output from the photosensor selecting section **7** and when distance data **X**, shuttering time data **T**, stopping data **F**, and position change

5   detection data **B** are output from the overall control section **11**, their associated modulation pattern P (A, X, T, F, B) is read out. As already described, the target value of deformation of the deformable mirror **4** to achieve appropriate imaging performance can be determined by the angle α and

10   distance **x**. The address **A** represents the angle α and the distance data **X** represents the distance **x**. The shuttering time data **T**, stopping data **F** and position change detection data **B** will be described in detail later.

On the substrate **4a** of the deformable mirror **4**, provided

15   is a driver circuit for applying a drive voltage to the respective actuators **4c** in accordance with the modulation pattern P (A, X, T, F, B) supplied from the modulation control section **8**. In this preferred embodiment, the displacement of the respective micromirrors **4b** is controlled as a closed loop,

20   and a drive voltage calculated based on the target degree of

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displacement is applied to each actuator **4c**, thereby realizing

a multistage displacement of the micromirrors **4b**.

The photodetector **5** is implemented as a CCD image sensor

or a CMOS image sensor in which pixels are arranged as a two-

5   dimensional array.

Next, the photodetector **5** will be described in detail

with reference to FIG. 3, which shows a schematic

configuration for the photodetector of this preferred

embodiment.

10   The photodetector **5** includes 1280 × 1280 pixels in total.

The photosensitive region **40** of the photodetector **5** is divided

into five horizontally and five vertically. Each of these 5 ×

5 photosensitive areas **40(1, 1)** through **40(5, 5)** includes 256

× 256 pixels and can be accessed on an area-by-area basis.

15   For that purpose, the same number of horizontal scanning

circuits **41(1)** through **41(5)** as the horizontal division number

of the photosensitive region **40** and the same number of

vertical scanning circuits **42(1)** through **42(5)** as the vertical

division number of the photosensitive region **40** are provided.

20   An area selector **43** receives the address **A** from the

photosensor selecting section **7**, and selects one of the photosensitive areas to activate. Supposing i and j are natural numbers of 1 to 5 and each photosensitive area is represented by 40(i, j), the address **A** includes data

5 specifying these i and j values. More specifically, the area selector **43** picks one horizontal scanning circuit **41(j)** and one vertical scanning circuit **42(i)** that are associated with the photosensitive area **40(i, j)** to activate, and sequentially scans the 256×256 pixels included in that area. The outputs

10 of the photodiodes of the respective pixels are amplified and digitized by a processor **44**, thereby obtaining output data **D(A)**. The output data **D(A)** means a sequence of data representing all pixels of the photosensitive area specified by the address **A**.

15 While an imaging operation is being carried out at the photosensitive area **40(i, j)**, the shape of the reflective surface of the deformable mirror **4** is controlled such that the incoming light has the smallest aberration at the center of the photosensitive area **40(i, j)** during the imaging operation.

20 Suppose the imaging operation is now being carried out at the

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photosensitive area **40(1, 1).** In that case, appropriate imaging performance is achieved within the dashed circle **C** including the photosensitive area **40(1, 1).** Synchronously with the operation of selecting the photosensitive area **40(i, j)** in

5   which the imaging operation should be carried out, the area with appropriate imaging performance as indicated by the dashed circle **C** is defined on the photosensitive area **40(i, j).** Accordingly, an image with appropriate imaging performance can be obtained over all photosensitive areas. To

10 acquire an image corresponding to one frame, the output data **D** may be sequentially obtained from all of the 25 photosensitive areas in the order of **40(1, 1), 40(1, 2), 40(1, 3),** … and **40(5, 5).** Optionally, those photosensitive areas may be selected at random as well. As another alternative, imaging

15 may also be carried out with only a required range selected from one frame. For example, to pick up a moving picture, motion estimation may be performed on every photosensitive area. However, if the variation from the previous frame image is less than a predetermined level in a photosensitive area,

20 then the imaging operation for the next frame may be omitted

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but the image data for the current frame may be used as it is. In any case, the modulation pattern **P** is selected synchronously with the photosensitive area selecting operation such that the deformable mirror **4** always provides appropriate

5 imaging performance for the photosensitive area that performs detecting operation effectively.

The number of modulation patterns **P** will be described. The photosensitive areas **40(1, 1)**, **40(1, 5)**, **40(5, 1)** and **40(5, 5)** are arranged so as to have rotation symmetry. In the

10 same way, their associated modulation patterns **P(A, X, T, F, B)** also have rotation symmetry as to a parameter of the address **A**. Accordingly, if one modulation pattern **P(A, X, T, F, B)** is rotated 90 degrees, for example, another modulation pattern **P(A', X, T, F, B)** may be obtained. By utilizing such

15 symmetry, the number of modulation patterns to be stored in the memory **12** can be reduced to as small as 5 against 25 addresses **A**, for example.

Also, as described above, if the surface of the deformable mirror **4** is kept flat without being deformed,

20 appropriate imaging performance is supposed to be achieved at

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the photosensitive area **40(3, 3)**, which is located at the

center of all photosensitive areas **40(1, 1)** through **40(5, 5)**.

While a focus control operation is being carried out by the

lens moving mechanism **3**, the lens **2** is moved to a location

5 with the highest pixel-to-pixel contrast by using this

photosensitive area **40(3, 3)**.

Referring back to FIG. 1, the overall configuration of

the optical detection system will be further described.

During an imaging operation for one frame, the

10 photosensor selecting section **7** sequentially switches the

address **A** values, thereby obtaining the output data **D(A)** from

all of the 25 photosensitive areas. In picking up a moving

picture, this operation is repeatedly performed. As described

above, the address **A** is output to the photodetector **5** and

15 modulation control section **8**, thereby synchronizing the

imaging operation by the photodetector **5** and the incoming

light modulating operation by the deformable mirror **4** with

each other. Furthermore, the address **A** is output to the image

reconstructing section **9**, too.

20 The modulation control section **8** generates the modulation

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pattern **P(A, X, T, F, B)** to drive the deformable mirror **4**.

The modulation pattern **P(A, X, T, F, B)** represents a target

degree of deformation of each micromirror **4b** and is a function

of the address **A** supplied from the photosensor selecting

5 section **7** and the distance data **X**, shuttering time data **T**,

stopping data **F** and position change detection data **B** supplied

from the overall control section **11**. In the memory **12** of the

modulation control section **8**, modulation patterns **P(A, X)** for

correcting an aberration, produced when an address **A** and

10 distance data **X** are given, to realize appropriate imaging

performance are calculated or obtained in advance via

experiments and stored. These modulation patterns are stored

as a table of correspondence between the addresses **A** and

distance data **X**. Thus, in response to the given address **A** and

15 distance data **X**, their associated modulation pattern **P(A, X)**

is read out. This modulation pattern **P(A, X)** is further

modulated by the modulation control section **8** in accordance

with the shuttering time data **T**, stopping data **F** and position

change detection data **B**, thereby generating the modulation

20 pattern **P(A, X, T, F, B)** finally.

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The image reconstructing section **9** receives the address **A**

from the photosensor selecting section **7** and the output data

D(A) from the photodetector **5**, respectively, so as to

reconstruct an image corresponding to one frame. The output

5   data **D(A)** of the photosensitive area, specified by the address

A, is temporarily stored in a memory **13**. When the output data

of all of the photosensitive areas are accumulated there,

those output data are merged with each other, thereby making

up one complete image. The image data compression processing

10   is also carried out by the image reconstructing section **9**.

The data compression processing may be selectively performed

by one of the following two methods. Specifically, according

to one method, a full-screen non-compressed image is obtained

by merging together the non-compressed image portions supplied

15   from the respective photosensitive areas and then subjected to

data compression. In the other method, the respective image

portions are subjected to image compression such as a two-

dimensional DCT in the respective photosensitive areas and

then merged together. The second method is advantageous in

20   that the capacity of the memory **13** can be cut down and that

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the processing rate can be increased. After having been subjected to data compression by any of these two methods, the full-screen image is stored in the image storage section **10**. The image storage section **10** is a removable memory such as a

5 flash memory card.

The overall control section **11** includes a focus control section **14**, a light quantity detecting section **15** and a position change detecting section **16** and controls the overall operation of the optical detection system.

10 The focus control section **14** controls the lens moving mechanism **3** to move the lens **2** to an in-focus position according to the distance **x** between this optical detection system and the object **Y**. The lens position may be adjusted by directly measuring the distance **x** with a range finder.

15 However, in this preferred embodiment, the lens **2** is moved to a position near the optical axis, at which the contrast in the photosensitive area becomes the highest with the deformable mirror **4** kept flat. The focus control section **14** outputs the information about the position of the lens **2** in such a

20 situation as the distance data **X** on the distance **x**.

The light quantity detecting section **15** is an exposure

meter, which adopts a matrix photometry method and which

detects the quantities of light at a plurality of photometric

points, thereby making illuminance data. The photometric

5   points, at which the light quantity detecting section **15**

measures the light quantities, are associated with the

respective photosensitive areas of the photodetector **5**. In

this preferred embodiment, 25 ($=5\times5$) photometric points are

provided. The outputs from these photometric points are

10   handled as illuminance data **I(A)** so as to be associated with

the addresses **A**. Also, either "stopping preferred" or

"shutter speed preferred" is selectively input through a user

interface (I/F) to the overall control section **11**, thereby

inputting a stopping value or a shutter speed value. Based on

15   these data and the illuminance data **I(A)**, the shuttering time

data **T(A)** and stopping data **F(A)** are determined for each

photosensitive area. The shuttering time data **T(A)** and

stopping data **F(A)** may be either constant irrespective of the

addresses **A** or variable with the addresses **A**. As a result,

20   the light quantity control can be carried out much more

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flexibly.   Thus, uniform light quantity control over the

entire photodetector **5** can be achieved more easily.

Furthermore, even in an image that has such a big difference

in brightness within itself to maintain an appropriate dynamic

5   range easily, it is possible to effectively prevent that image

from being whitened or blackened entirely by controlling the

light quantity on a photosensitive area basis. Alternatively,

the overall control section **11** may also be designed so as to

allow the user to pick the "stopping preferred" option or the

10   "shutter speed preferred" option on an image area basis.   In

that case, a picture of a special type can be created by

bringing about different effects on respective photosensitive

areas.   For example, some photosensitive areas may give an

impression of gentle flow with the shutter speed decreased,

15   while other photosensitive areas within the same picture may

give an impression of a series of instantaneous photos that

were taken with the shutter speed increased.

In order to correct the blurring, the position change

detecting section **16** detects the position change of the

20   housing **1**.   The position change detecting section **16** includes

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two angular velocity sensors (not shown), which respectively detect the pitching and yawing angular velocities of the housing 1. These angular velocity outputs are integrated together by an integrator, thereby calculating position change detection data **B** about the change in the position of the housing 1 at regular intervals as the total positional change from the start of imaging. The position change detection data **B** calculated in this manner is output to the modulation control section **8**.

Hereinafter, it will be described how the optical detection system having such a configuration operates.

When the shutter button (not shown) is pressed down halfway, the overall control section **11** performs a focus control first. Specifically, the overall control section **11** gets the lens **2** slightly moved forward or backward by the lens moving mechanism **3**, thereby searching for a position near the optical axis of the photodetector **5** at which the contrast is maximized in the photosensitive region. In this case, no drive voltage is applied to the deformable mirror **4** and the reflective surface of each micromirror **4b** is flat. When the

position of the lens **2** is controlled at the in-focus position, the distance data **X** in that situation is generated.

Next, the light quantity detecting section **15** outputs the illuminance data **I(A)** obtained from the respective photometric

5   points. The overall control section **11** compares the pattern of this illuminance data **I(A)** with multiple prestored illuminance pattern data, thereby sensing the image situation and picking the shuttering time data **T(A)** and stopping data **F(A)** that seem to be the best at this time. These distance

10   data **X**, shuttering time data **T(A)** and stopping data **F(A)** are output to the modulation control section **8**.

The preparatory operation that has been carried out in response to the half-pressing of the shutter button is finished in this way. When the shutter button is pressed next

15   time, the overall control section **11** will start an imaging operation. First, the position change detecting section **16** detects the biaxial angular velocities of the housing **1** and integrates together these angular velocity outputs from the imaging start point, thereby outputting position change

20   detection data **B**.

The photosensor selecting section 7 sequentially switches

the addresses **A** and outputs them to the photodetector 5 and

modulation control section **8**. In this manner, the respective

photosensitive areas of the photodetector 5 are selectively

5 activated effectively, while at the same time, the modulation

control section **8** generates a modulation pattern **P(A, X, T, F,**

B) to produce appropriate imaging performance in the

respective photosensitive areas. In accordance with the

modulation pattern **P(A, X, T, F, B)** supplied from the

10 modulation control section **8**, the deformable mirror **4**

displaces the respective micromirrors **4b**, thereby modulating

the incoming light. Also, the deformable mirror **4** corrects

the position of the focal point in accordance with the

position change detection data **B**, corrects the aberration due

15 to the angle of view and so on based on the address **A** and

distance data **B**, and controls the quantity of light falling on

the active photosensitive area according to the shuttering

time data **T(A)** and stopping data **F(A)**.

Furthermore, the photodetector 5 performs a discrete

20 sampling operation in a spatial period to be determined by a

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pixel-to-pixel pitch. To prevent moiré fringes from being produced due to this aliasing error, the deformable mirror **4** also functions as an optical low pass filter.

These stopping, shuttering, low pass filtering and blurring correcting operations of the deformable mirror **4** during the imaging operation will be described with reference to FIGS. **4** through **6**. FIG. **4** illustrates how the deformable mirror **4** performs the stopping and shuttering operations.

FIG. **4(a)** illustrates a state of the deformable mirror **4** corresponding to an "aperture fully opened" state. In the photodetector **5**, an activated photosensitive area thereof, which is carrying out the light detecting operation effectively, will be identified by G. The other area of the photodetector **5**, as well as the areas outside of the photodetector **5**, will be referred to herein as a "non-photosensitive area". In FIG. **4(a)**, the respective micromirrors **4b** are deformed such that the aberration is minimized at the center of the photosensitive area **G**. As already described, the condition to realize this state is to determine the optical path lengths so as to equalize the phase

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conditions of incoming light rays following the respective

optical paths. In this case, the deformable mirror **4** does not

particularly function as a diaphragm and its state corresponds

to the "aperture fully opened" state.

5   FIG. **4(b)** illustrates a state of the deformable mirror **4,**

which is deviating all incoming light rays outside of the

photosensitive area **G.** The condition to realize this state is

to determine the optical path lengths so as to produce

mutually canceling interferences within the photosensitive

10 area **G** because the incoming light rays following the

respective optical paths have significantly different phase

conditions. For example, the respective micromirrors **4b** may

be tilted to a tilt angle, which is significantly different

from the position shown in FIG. **4(a).** Alternatively, the

15 micromirrors **4b** may define a blazed diffraction grating, high-

order (i.e., higher than the first order) light rays may be

deviated outside of the photosensitive area **G** and their light

quantity ratio may be increased up to almost 100%. There are

a lot of solutions that realize such a condition. Thus, an

20 appropriate one of them may be selected and adopted as the

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modulation pattern. As a result, the photosensitive area **G** can be shielded from the incoming light substantially completely.

The photosensitive area **G** is just a portion of the entire

5 photosensitive region of the photodetector **5**. Accordingly, even if the photodetector **5** and deformable mirror **4** are provided rather close to each other, the incoming light can be deviated toward the non-photosensitive area easily. Thus, compared with the situation where the incoming light must be

10 deviated totally outside of the photodetector **5** as in the conventional optical detection system, the distance between the photodetector **5** and the deformable mirror **4** can be shortened significantly.

FIG. **4(c)** illustrates a state of the deformable mirror **4**,

15 which is defining an iris diaphragm. Just like the respective micromirrors **4b** shown in FIG. **4(a)**, the micromirrors **4b** within an area **S** of the deformable mirror **4** are deformed such that the aberration is minimized at the center of the photosensitive area **G**. On the other hand, just like the

20 respective micromirrors **4b** shown in FIG. **4(b)**, the

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micromirrors **4b** outside of the area **S** of the deformable mirror **4** deviate the incoming light rays outside of the photosensitive area **G**. Accordingly, this area **S** corresponds to the aperture of an iris diaphragm, the incoming light ray

5   within this iris reaches the photosensitive area **G** but the other incoming light rays are substantially cut off. The size of the area **S** is determined by the stopping data **F**. Also, the deformable mirror **4** is operated as shown in FIG. **4(c)** only within a period of time defined by the shuttering time data **T**

10   but operated as shown in FIG. **4(b)** in the other periods. As a result, the incoming light ray is allowed to reach the photosensitive area **G** only within the period of time defined by the shuttering time data **T** and the deformable mirror **4** can function as both an iris diaphragm and a shutter alike.

15   The aperture size of the iris diaphragm and the shuttering time can be changed on a photosensitive area **G** basis. Thus, the best aperture size and the best shuttering time can be used for each photosensitive area **G**. Generally speaking, the iris diaphragm tends to work relatively easily

20   around the center of one's vision but not so easily around the

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periphery of the vision, although it actually depends on the design of the optical system adopted. Accordingly, if the variation in the aperture size of the iris diaphragm is decreased in photosensitive areas around the center of the

5 photodetector but increased in photosensitive areas around the periphery of the photodetector, the light quantity can be made uniform relatively easily. Naturally, the iris diaphragm shape can be defined arbitrarily. Thus, by optimizing that shape, the light quantity can be made even more uniform.

10   Next, the optical low pass filtering operation of the deformable mirror **4** will be described with reference to FIG. **5**, which illustrates how the deformable mirror **4** functions as an optical low pass filter.

       As already described, the micromirrors **4b** within the area

15 **S** of the deformable mirror **4** are deformed so as to minimize the aberration in the photosensitive area **G**, which is performing a photosensing operation effectively in the photodetector **5**. However, to further function as an optical low pass filter, the micromirrors **4b** within that area **S** form

20 two focal points **Ya'1** and **Ya'2** with respect to an object **Ya**,

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speaking microscopically. These two focal points **Ya'1** and

Ya'2 are separate from each other just by the pixel pitch **p** of

the photodetector **5**. As a result, optical signal components

falling within a range corresponding to the Nyquist rate of

5   the photodetector **5** are cut off. Consequently, the optical

low pass filtering function of reducing the aliasing error of

the photodetector **5** during its sampling operation and

eliminating the moirés is achieved. To separate the focal

point into those two points **Ya'1** and **Ya'2**, some of the

10   micromirrors **4b** within the area **S** may have their position

controlled so as to focus the incoming light at the point **Ya'1**

and the other micromirrors **4b** may have their position

controlled so as to focus the incoming light at the point

Ya'2. This control is also realizable just by changing the

15   modulation pattern **P** output by the modulation control section

8. Also, the actual focal points are not two but four in

three directions, i.e., two focal points along a horizontal

line of pixels in the photodetector **5** and two more focal

points along two oblique lines of pixels, so that each pair of

20   focal points is separate from each other by a pixel pitch. To

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achieve the optical low pass filtering function effectively, every focal point within the photosensitive area **G** needs to be shifted from its adjacent focal point exactly by the pixel pitch **p**. There is a small difference in the magnitude of this

5   shift between around the center of the activated photosensitive area **G** and around the periphery thereof. However, if the size of the photosensitive area **G** is reduced sufficiently, such an error can be reduced to a negligible level.

10   In the prior art, such an arrangement forming multiple focal points that are shifted from each other by the pixel pitch **p** is normally realized by combining together birefringent members made of quartz, for example. In contrast, according to the present invention, an optical low

15   pass filter that minimizes the moirés can be obtained without using any special member. Also, the conventional optical low pass filter using those birefringent members requires that the incoming light be non-polarized light. However, according to the present invention, an optical low pass filter that can be

20   always used irrespective of the polarization direction of the

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incoming light can be provided without being limited by any such constraint.

Next, the blurring correcting operation of the deformable mirror **4** will be described with reference to FIG. 6, which illustrates how the deformable mirror **4** corrects the blurring.

Suppose at the start of imaging operation, an incoming light ray that has come from a point **Ya(0)** of the object **Y** enters the system at an angle $\alpha(0)$ and focused at a point **Ya'** on the photodetector **5**. As already described, the angle $\alpha(0)$ is defined by the address **A** that specifies a selected photosensitive area and the deformable mirror **4** is deformed so as to equalize the phase conditions of incoming light rays following the respective optical paths from the point **Ya(0)** to the point **Ya'**.

When the housing **1** changes its direction due to blurring, it seems to the housing **1** as if the object **Y** had moved.

When an amount of time **t** passes from the start point of imaging operation, the point **Ya(0)** will shift to a point **Ya(t)** and the angle of incidence of the incoming light ray will change by $\alpha(t) - \alpha(0)$. The deformable mirror **4** controls the

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magnitude of displacement to keep the focal point **Ya'** unmoved

by compensating for that variation $\alpha(t) - \alpha(0)$ in the angle of

incidence of the incoming light ray. This control is achieved

by deforming the deformable mirror **4** so as to equalize the

5 phase conditions of incoming light rays following the

respective optical paths from the point **Ya(t)** to the point

Ya'. The magnitude of displacement satisfying this condition

can be obtained substantially automatically when the angular

variation $\alpha(t) - \alpha(0)$ is known. And this angular variation α

10 $(t) - \alpha(0)$ is given as the position change detection data **B**

output by the position change detecting section **16**. Thus, the

modulation control section **8** can generate a modulation pattern

for blurring correction based on this position change

detection data **B**.

15   As described above, just by changing the modulation

pattern **P(A, X, T, F, B)**, the deformable mirror **4** can perform

the aberration correcting function, stopping function,

shuttering function, optical low pass filtering function

and/or blurring correcting function simultaneously in an

20 arbitrary combination, thus contributing to significant

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simplification and size reduction of the overall system. Also, the aperture size of the iris diaphragm and the shuttering time can be defined on a photosensitive area basis. Consequently, the light quantity can be controlled uniformly

5 over the entire area of the photodetector.

As described above, the optical detection system of this preferred embodiment is designed such that the photosensor selecting section 7 selects one of multiple photosensitive areas of the photodetector 5, in which a photosensing

10 operation can be performed effectively, and that the modulation control section 8 generates a modulation pattern that achieves appropriate imaging performance in that photosensitive area. Accordingly, even with a simple optical system, the aberration due to the angle of view can be reduced

15 effectively over the entire area of the photodetector 5.

In addition, in the preferred embodiment described above, the modulation control section 8 is designed so as to control the quantity of light entering the activated photosensitive area G by deviating a portion of the incoming light on the

20 deformable mirror 4 outside of the activated photosensitive

area **G**. Thus, the single deformable mirror **4** can function as both an aberration correcting mechanism and a light quantity control mechanism alike, thereby simplifying the optical system.

5   Furthermore, in the preferred embodiment described above, the incoming light that has been deviated outside of the activated photosensitive area **G** is focused on other photosensitive areas of the photodetector **5**. Thus, compared with the situation where the incoming light must be deviated

10 totally outside of the photodetector **5** as in the prior art, the distance between the photodetector **5** and the deformable mirror **4** can be shortened significantly and the optical detection system can be downsized.

Furthermore, in the preferred embodiment described above,

15 the modulation control section **8** is designed so as to generate a modulation pattern that compensates for a shift of the focal point in accordance with the output of the position change detecting section **16**. Accordingly, the single deformable mirror **4** can function as a blurring correcting mechanism, too,

20 thus further simplifying the optical system.

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Furthermore, in the preferred embodiment described above, the modulation control section **8** is designed so as to generate a modulation pattern that focuses the incoming light at multiple points that are separate from each other by the pixel

5 pitch of the photodetector **5**.   Accordingly, the single deformable mirror **4** can also function as an optical low pass filter, thus further simplifying the optical system.

Furthermore, in the preferred embodiment described above, the optical detection system is designed such that the

10 photosensor selecting section **7** selects the photosensitive area to activate from multiple photosensitive areas of the photodetector **5**, and that the modulation control section **8** generates an appropriate opaque pattern for that photosensitive area.   Thus, the light quantity can be

15 controlled independently on a photosensitive area basis. Consequently, compared with the situation where the light quantities of all areas of the photodetector are controlled at a time with just one opaque pattern as in the prior art, the constraint on the arrangement and design of the opaque member

20 can be relaxed significantly and the overall system can be

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downsized.

In the preferred embodiment described above, the address **A** is used as a piece of information specifying a particular photosensitive area of the photodetector **5** and the modulation

5   control section **8** outputs a modulation pattern **P** in accordance with that information. Optionally, the address **A** may further include additional information specifying the respective colors of R, G and B and the modulation control section **8** may output a modulation pattern **P** in accordance with that

10 information. As a result, a chromatic aberration due to the difference in wavelength between the respective colors of R, G and B can be reduced effectively.

Also, in the preferred embodiment described above, the lens **2** is supposed to be a single bi-convex lens. However,

15 the lens **2** may be modified according to any normal optical design technique. For example, the lens **2** may have any other lens shape such as a meniscus lens, may be a compound lens, may be combined with a diffraction element or may even be replaced with a reflective mirror with concave and convex

20 surfaces. By appropriately adopting these modifications,

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various design options can be provided. For example, the

chromatic aberration may be minimized by modifying the lens

design but the aberration due to the angle of view may be

eliminated by the deformable mirror. As a result, the optical

5   system can be simplified adequately, some of the aberrations

due to the angle α, distance x and wavelength difference can

be reduced and yet the number of modulation patterns P to be

provided can be reduced as well.

Furthermore, in the preferred embodiment described above,

10   the focus is controlled by getting the lens 2 moved by the

lens moving mechanism 3.   Alternatively, the lens moving

mechanism 3 may be omitted and the lens 2 may be fixed on the

housing 1. Such a configuration is obviously the best choice

when the lens 2 has a large depth of field and this optical

15   detection system is used as a performance camera. However,

even if the depth of field of the lens 2 is small, the lens

moving mechanism 3 for use in focus control can be omitted by

creating a wavefront, equivalent to that obtained by getting

the lens 2 moved along the optical axis by the lens moving

20   mechanism 3, with the deformable mirror 4.

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Furthermore, a member equivalent to the lens 2 may also be omitted. That is to say, the deformable mirror 4 may create a focusing plane and form a focal point on the photodetector 5. In such a configuration, the system can be

5 further downsized and the number of parts members can be further reduced. In addition, the generation of chromatic aberrations can be minimized without performing any special control.

Also, in the preferred embodiment described above, each

10 photosensitive area of the photodetector 5 includes 256×256 pixels. However, this number was selected arbitrarily. Alternatively, one pixel may define one photosensitive area, for example. The number of photosensitive areas may also be defined arbitrarily. And the greater the number of

15 photosensitive areas, the more finely the aberration due to the angle of view can be corrected. Furthermore, one photometric point is defined per photosensitive area. However, it is naturally possible to provide a plurality of photometric points for each photosensitive area.

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EMBODIMENT 2

Hereinafter, an optical detection system according to a second preferred embodiment of the present invention will be described with reference to FIG. 7, which illustrates a

5   schematic configuration for an optical detection system according to the second preferred embodiment of the present invention.

In this preferred embodiment, the deformable mirror **4**, a photodetector **55**, and a controller **56** are fixed to the housing

10   **51** of the optical detection system.   The controller **56** includes a modulation control section **57**, the image storage section **10** and an overall control section **58**.   Also, a replaceable lens unit **52** is mounted on the housing **51**.   The deformable mirror **4** and image storage section **10** have the same

15   configurations as those already described for the first preferred embodiment.

The lens unit **52** is provided so as to be attachable to, and removable from, the housing **51** and to be replaceable with another lens unit.   In this preferred embodiment, the lens

20   unit **52** includes a concave lens portion **53a** and a convex lens

portion **53b**, which can shift independently of each other, so as to focus an incoming light ray, which has come from the object **Y** of imaging, on the photodetector **55** at multiple stages of imaging magnifications β. Supposing the concave

5 lens portion **53a** has a focal length of -70 mm, the convex lens portion **53b** has a focal length of 50 mm, and the magnification is from -1/2 to -1, the lens unit **52** will be a zoom lens consisting of two groups with $f = 35$ mm to 70 mm. In FIG. 7, the concave and convex lens portions **53a** and **53b** are

10 illustrated as single lenses for the sake of simplicity but may also be compound lenses as well. In this preferred embodiment, the aberration due to the angle of view and the chromatic aberration are supposed to be minimized to negligible levels in actual use by designing these lens

15 systems appropriately. Thus, it will be described how the deformable mirror **4** corrects the aberration caused by a variation in the state of the lens system when the imaging magnification β of the lens unit **52** is changed by shifting the concave and convex lens portions **53a** and **53b** and a high-

20 order aberration caused during a focusing operation according

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to the distance x to the object Y.

The lens unit **52** is provided with a lens information storage section **54**, which may be a nonvolatile memory, for example, and which stores information about the type of the

5   lens unit **52**, the allowable range of the imaging magnification β, and the imaging performance when the lens unit **52** forms a focal point on the object Y at the distance x and with the imaging magnification β. In this case, the imaging performance particularly relates to the aberration property of

10   the lens unit **52**. In this preferred embodiment, preferable modulation patterns for the deformable mirror **4**, which were obtained by either calculations or experiments as those contributing to correcting the aberrations in a most preferable manner when the lens unit **52** formed focal point on

15   the object Y at the distance x and with the imaging magnification β, are stored in the lens information storage section **54**. Those modulation patterns are stored as a table of correspondence with respect to the distance data X and imaging magnification data Z to be described later.

20   Also, the concave and convex lens portions **53a** and **53b**

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are provided with respective shifting mechanisms for shifting them independently of each other. The concave and convex lens portions **53a** and **53b** are controlled by the overall control section **58** so as to be driven independently of each other.

5   The lens unit **52** further includes an encoder (not shown) for sensing the respective positions of the concave and convex lens portions **53a** and **53b** and outputting their positional information to the overall control section **58**.

The photodetector **55** is implemented as a CCD image sensor

10   or a CMOS image sensor in which pixels are arranged as a two-dimensional array. The photodetector **55** may be the same as the photodetector **5** as described for the first preferred embodiment. In this preferred embodiment, however, the photodetector **55** is a normal frame scanning type image sensor,

15   of which the photosensitive region is not divided into multiple areas to be driven independently.

In accordance with the distance data **X** and imaging magnification data **Z** supplied from the overall control section **58**, the modulation control section **57** generates a modulation

20   pattern **P(X, Z)** to be output to the deformable mirror **4**. In

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the memory **59** of the modulation control section **57**, the modulation pattern table information, which has been read out from the imaging information storage section **54**, is stored. And in accordance with the distance data **X** and imaging

5   magnification data **Z** supplied from the overall control section **58**, the modulation pattern **P(X, Z)** is read out from the memory **59**.

The overall control section **58** includes a lens information sensing section **60**, a magnification control

10 section **61** and a focus control section **62** and controls the overall operation of the optical detection system.

The lens information sensing section **60** reads out the information from the lens information storage section **54**, thereby sensing the type of the given lens unit **52**. In

15 accordance with this information, the overall control section **58** updates the modulation pattern table information to be stored in the memory **59**.

In accordance with the user's operation command to increase or decrease the imaging magnification β , the

20 magnification control section **61** controls the positions of the

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concave and convex lens portions **53a** and **53b** and generates the imaging magnification data **Z** based on the resultant positions of the concave and convex lens portions **53a** and **53b**.

The focus control section **62** moves the concave and convex lens portions **53a** and **53b** to in-focus positions according to the distance **x** between this optical detection system and the object **Y**. As in the first preferred embodiment described above, it is determined by locating a position, where the pixel-to-pixel contrast in the output of the photodetector **55** has a local maximum value, whether the incoming light rays are in focus or not. In this case, the concave and convex lens portions **53a** and **53b** are shifted back and forth at small steps while satisfying a predetermined positional relationship. In this manner, the position where the pixel-to-pixel contrast of the photodetector **55** has a local maximum value is searched for.

Every time the concave and convex lens portions **53a** and **53b** are shifted, the distance data **X** is output and the modulation control section **57** generates a modulation pattern **P(X, Z)** based on this distance data **X**. Thus, the high-order

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aberration can be removed by driving the deformable mirror **4** and the contrast local maximum value can be searched for with appropriate imaging performance achieved. As a result, it can be determined rather accurately whether the incoming light rays are in focus or not. Also, based on the result of this decision, the focus control section **62** generates the distance data **X**.

The overall control section **58** outputs the imaging magnification data **Z** and distance data **X**, which have been generated in this manner, to the modulation control section **57**.

Hereinafter, it will be described how the optical detection system with such a configuration operates.

First, with the lens unit **52** attached to the housing **51**, the lens information sensing section **60** recognizes the type of the given lens unit **52**. The overall control section **58** reads out the information from the lens information storage section **54**, thereby updating the contents of the memory **59**. Next, in accordance with the user's zooming operation, the magnification control section **61** controls the positions of the

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concave and convex lens portions **53a** and **53b**, thereby determining the imaging magnification β and generating the imaging magnification data **Z**.

When the user presses down the shutter button (not shown)
5 halfway, the overall control section **58** performs a focus control first. Specifically, the focus control section **62** shifts the concave and convex lens portions **53a** and **53b**, thereby searching for in-focus positions and determining the distance data **X**.

10 During the imaging operation, the modulation control section **57** generates the modulation pattern **P(X, Z)** based on these distance data **X** and imaging magnification data **Z** and the deformable mirror **4** is deformed according to this modulation pattern **P(X, Z)**. And by deforming the deformable mirror **4**,
15 the aberration of the lens unit **52** can be corrected and an appropriate image is formed on the photodetector **55**. The output data **D** of the photodetector **55** is stored in the image storage section **10**.

As described above, the optical detection system of this
20 preferred embodiment is designed such that the imaging

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magnification setting of the zooming lens unit **52** is sensed by the magnification control section **61** and that the modulation control section **57** achieves appropriate imaging performance according to the imaging magnification sensed. Accordingly, even if the optical system of the lens unit **52** is simplified, it is possible to effectively reduce the aberration to be generated when the imaging magnification of the lens unit **52** is changed.

Also, the optical detection system of this preferred embodiment is designed such that information about the imaging performance of the lens unit **52** is stored in the lens information storage section **54**, which is provided as an integral part of the lens unit **52**, and is sensed by the lens information sensing section **60** and that the modulation control section **57** achieves appropriate imaging performance in accordance with that information. Accordingly, even if the lens unit **52** is replaced with another lens unit **52** with a quite different imaging performance, the aberration can still be reduced effectively. Consequently, even in handling multiple lens units with various imaging performances (e.g.,

from a telescopic one to a wide angle one), their aberrations can be corrected effectively with their optical systems simplified. Or even when multiple lens units of the same types are handled, the variation in characteristic among the

5   individual lens units can be corrected as well. That variation in characteristic among the individual lens units can be corrected effectively by storing the test data of the respective lens units in the lens information storage section 54.

10   The preferred embodiment described above is a configuration for correcting the aberrations associated with the imaging magnification β and distance x. Optionally, the configuration of this preferred embodiment may be combined with the configuration for correcting the aberration due to

15   the angle of view and the chromatic aberration as described for the first preferred embodiment.

Also, in the preferred embodiment described above, the imaging performance information about the lens unit 52 to be stored in the lens information storage section 54 is the table

20   information representing the modulation pattern generated by

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the modulation control section 57. However, the present

invention is in no way limited to that specific preferred

embodiment. For example, that information may represent the

aberration data of the lens unit 52 as respective coefficients

5   of a Zernike polynomial.

EMBODIMENT 3

Hereinafter, an optical detection system according to a

third preferred embodiment of the present invention will be

10 described with reference to FIG. 8. In this preferred

embodiment, portions of the spatial light modulator and

photosensor selecting section are implemented as a liquid

crystal element and the photodetector is implemented as a

photosensitive film. FIG. 8 illustrates a schematic

15 configuration for an optical detection system according to the

third preferred embodiment of the present invention.

In this preferred embodiment, the lens 2, the lens moving

mechanism 3, a liquid crystal phase modulator 72, a liquid

crystal shutter 73, a photosensitive film 74 and a controller

20 75 are fixed to the housing 71 of the optical detection

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system. The controller **75** includes a photosensing selector **76**, a modulation control section **77**, and an overall control section **78**. The lens **2** and lens moving mechanism **3** have the same configurations as those already described for the first

5 preferred embodiment.

The liquid crystal phase modulator **72** is obtained by injecting a liquid crystal material with an analog phase modulating property such as a nematic liquid crystal material or a deformed helix ferroelectric (DHF) liquid crystal

10 material between two glass substrates with matrix transparent electrodes. The liquid crystal phase modulator **72** modulates the phase of the incoming light ray by controlling the voltage between these transparent electrodes. On the light incoming side of the liquid crystal phase modulator **72**, a first

15 polarizer is provided such that a linearly polarized light ray is incident on the liquid crystal layer. Furthermore, both of the two glass substrates are subjected to an alignment treatment such that the liquid crystal molecules are oriented in this polarization direction. Thus, the incoming light ray

20 being transmitted through the liquid crystal phase modulator

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72 can have its optical path length controlled without changing its polarization direction. The liquid crystal phase modulator 72 may be made up of as many as 512×512 modulation elements, which are driven with multi-stage drive voltages so as to achieve a smooth phase conversion control. Also, the liquid crystal phase modulator 72 further includes a driver circuit (not shown) and modulates the phase in accordance with the modulation pattern P supplied from the modulation control section 77.

The liquid crystal shutter 73 is obtained by injecting a ferroelectric liquid crystal material between two glass substrates with matrix transparent electrodes, and controls the voltage between the transparent electrodes digitally (i.e., into either ON state or OFF state), thereby transmitting or cutting off the incoming light on an area-by-area basis. The liquid crystal layer of the liquid crystal shutter 73 is provided such that the liquid crystal molecules thereof are oriented parallel to the polarization direction of the incoming light ray. The liquid crystal shutter 73 is designed not to change the polarization direction of the incoming light

ray when no voltage is applied between the transparent electrodes but to change the polarization direction of the incoming light ray due to the birefringence of the liquid crystal layer when a voltage is applied between the

5   transparent electrodes.   On the light outgoing side of the liquid crystal shutter **73**, a second polarizer is provided. The second polarizer is arranged such that the polarization direction thereof is perpendicular to that of the first polarizer provided for the liquid crystal phase modulator **72**.

10   Accordingly, when a voltage is applied between the transparent electrodes of the liquid crystal shutter **73**, the incoming light ray has its polarization direction rotated approximately 90 degrees and is transmitted through the liquid crystal shutter **73**.   However, when no voltage is applied

15   between the transparent electrodes of the liquid crystal shutter **73**, the incoming light ray never has its polarization plane changed and is cut off by the shutter **73**.

The number of opaque members that make up the liquid crystal shutter **73** may be about 5 × 5, for example.   By

removing the voltage from only selected ones of the opaque members, the incoming light ray can be transmitted through just arbitrary ones of those areas. The liquid crystal shutter **73** further includes a driver circuit (not shown) and

5   transmits the incoming light ray through a location specified by the address **A** given from the photosensing selector **76**, thereby exposing a portion of the photosensitive film **74**, associated with that location, to the incoming light ray. In this arrangement, the photosensitive film **74** is divided into

10   25 photosensitive areas. That photosensitive area to be exposed to the incoming light ray in response to the address **A** will be referred to herein as an "activated photosensitive area".

The photosensitive film **74** is a normal photographing film

15   and is a storage medium that changes its physical property due to a chemical reaction caused by exposure, thereby forming an image or a latent image thereon. The photosensitive film **74** is provided either in contact with, or at least very close to, the liquid crystal shutter **73**.

During an imaging operation for one frame, the photosensing selector **76** sequentially switches the address **A** values, thereby exposing the 25 photosensitive areas to the light one after another. The addresses **A** generated by the

5 photosensing selector **76** are also output to the modulation control section **77** at the same time, thereby synchronizing the photosensitive area selecting operation by the liquid crystal shutter **73** and the incoming light modulating operation by the liquid crystal phase modulator **72** with each other.

10 The modulation control section **77** generates the modulation pattern **P(A, X, T, F, B)** to drive the liquid crystal phase modulator **72**. The contents of the modulation pattern **P(A, X, T, F, B)** and the addresses **A**, distance data **X**, shuttering time data **T**, stopping data **F**, and position change

15 detection data **B** are almost the same as those described for the modulation control section **8** of the first preferred embodiment.

The overall control section **78** includes a focus control section **80**, the light quantity detecting section **15** and the

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position change detecting section **16** so as to control the overall operation of the optical detection system. The light quantity detecting section **15** and position change detecting section **16** are the same as those already described for the

5 modulation control section **8** of the first preferred embodiment. The focus control section **80** includes a range finder (not shown) to detect the distance **x** between this optical detection system and the object **Y** and controls the lens moving mechanism **3** to shift the lens **2** to an in-focus position according to

10 this distance **x**. Also, the focus control section **14** outputs the distance data **X** representing this distance **x**.

Hereinafter, it will be described how the optical detection system with such a configuration operates.

When the shutter button (not shown) is pressed down

15 halfway, the overall control section **78** performs a focus control first. Specifically, the distance **x** is measured by activating the range finder of the focus control section **80**, the lens **2** is shifted to the in-focus position by the lens moving mechanism **3**, and the distance data **X** is output to the

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modulation control section **77**.

Next, the light quantity detecting section **15** outputs the illuminance data **I(A)** obtained from the respective photometric points. Based on this illuminance data **I(A)**, the overall

5 control section **78** determines the shuttering time data **T(A)** and stopping data **F(A)** and outputs them to the modulation control section **77**.

The preparatory operation that has been carried out in response to the half-pressing of the shutter button is

10 finished in this way. When the shutter button is pressed next time, the overall control section **78** will start an imaging operation. First, the position change detecting section **16** detects the biaxial angular velocities of the housing **1** and integrates together these angular velocity outputs from the

15 imaging start point, thereby outputting position change detection data **B**.

The photosensing selector **76** sequentially switches the addresses **A** and outputs them to the liquid crystal shutter **73** and modulation control section **77**. In this manner, only a

20 selected portion, specified by the address **A**, is no longer

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shielded by the liquid crystal shutter **73** and a portion of the

photosensitive film **74** in that activated photosensitive area

is exposed to the incoming light. At the same time, the

modulation control section **77** generates a modulation pattern

5 **P(A, X, T, F, B)** to produce appropriate imaging performance in

the respective photosensitive areas. In accordance with the

modulation pattern **P(A, X, T, F, B)** supplied from the

modulation control section **77**, the liquid crystal phase

modulator **72** modulates the incoming light. As a result of

10 this modulation control, the aberration due to the angle of

view can be corrected, the quantity of light falling on the

photosensitive area can be controlled and the blurring can be

corrected.

As described above, the optical detection system of this

15 preferred embodiment includes the liquid crystal shutter **73**

and photosensing selector **76**, which are used to selectively

transmit or cut off the incoming light ray through/from the

photosensitive film **74**. And the optical detection system is

designed such that the modulation control section **77** generates

20 a modulation pattern that realizes an appropriate imaging

performance in the photosensitive area that has been selected by the liquid crystal shutter **73** and photosensing selector **76**. Accordingly, even with a simple optical system, the aberration due to the angle of view can be reduced effectively over the

5 entire area of the photosensitive film **74**.

INDUSTRIAL APPLICABILITY

According to the present invention, a modulation control section to control a spatial light modulator generates a

10 modulation pattern that contributes to achieving an appropriate imaging performance in response to a change in any of various factors including the angle of view and imaging magnification. Thus, reduction of the aberration or appropriate control of the light quantity over the entire area

15 of the photodetector and simplification of the optical system can be achieved at the same time.